

A Utility Rate Model for Water and Wastewater: Concept and Issues

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Abstract

Utility Rate studies for water and sewer are commonly utilized by cities and counties to determine the appropriate rate to be charged for services. These rate studies are pricing models that consider numerous variables that comprise various influences to determine an optimal pricing strategy. This study examines the elements of a utility rate model that are used to create an economic and equity balance for governmental agencies by sharing various methodologies for funding critical water and wastewater resources. Every nation on earth is faced with diminishing resources. Funding water and wastewater operations are vastly different in the United States not to mention around the world. This research defines a rate model that will provide numerous pricing options beneficial to any country.

Key words: pricing models, utility rate study, water, wastewater, forecasting, demand

1. Introduction

Utility Rate studies for water and sewer are commonly utilized by cities and counties to determine the appropriate rate to be charged for services. These rate studies are demand models that consider numerous variables that consider various influences to determine an optimal pricing strategy. This study examines the elements of a utility rate model that are used to create an economic, environmental, and equity balance for governmental agencies trying to serve the public and maintain a fair price for services. This research will include publicly operated water and wastewater considerations as we analyze the elements of a rate model.

Determining utility rates is an important element in the decision making process for government agencies. To that end, a good rate model is easily completed and monitored by the staff of the organizations they support. However, usually due to overall costs or civic mistrust in government, rate models are often completed by consultants to justify any proposed rate increase. It is not unusual for municipalities to hire short-term expertise to complete projects where permanently the hiring the human resources cannot be justified. In reality, there are many pitfalls to rate modeling and statistics can be manipulated to meet the needs of the analyst. This research will also explore some grey areas in rate modeling.

The overall purpose of this research is to analyze the development of a water and wastewater rate study for a publicly operated municipality. According to Gerasimos and Wang (2003), an effective rate model must address four issues; 1) revenues must cover costs, 2) price structure should encourage conservation, 3) revenue must be stable, and 4) administrative costs associated with collecting the revenue should be as low as possible. Building a solid model that addresses these four issues will enable governmental agencies to maintain confidence of consumers and provide a service to the public.

Rate models are complex and there is no true cookie cutter model that fits all situations. To accomplish the four issues listed there are many considerations including conservation incentives, number of meters, size of meters, commercial and residential customers, administrative considerations, age of facilities, capital improvements, etc. Many of these issues include trade-offs for political or economic reasons. Building the most efficient and cost effective system is the municipalities goal, but strategic planning for future use must also be considered. A true decision support rate model will provide managers with options for each element of the model and support the mission of the organization.

The ability to forecast future growth and consumption is another critical element of a rate model that is often minimized or overlooked. In 1995, a rate study by the City of Cape Coral Florida was rejected by City Council after opposition from citizens. The problem stemmed from erroneous data in a 1991 rate study that enabled revenues to be approximately \$10 million or 40 percent, below projections by the time a follow-up study was contracted (Anderson and Forrer, 2001). This research will include forecasting methodology and the importance of accurate data.

2. Literature Review

A successful rate model must meet requirements of the political, financial, environmental, and strategic plan for the municipality it supports. It is extremely important that the governing body is aware of all cost associated with the operation and maintenance of the utility. Additionally, it is important that charges are appropriate and ratepayers, not general tax payers, cover all costs associated with the utility. According to

Gerasimos and Wang (2003), the following goal development process must address;

- 1) Revenue Generation: the utility must cover its costs and by law can only exceed costs by a limited amount.
- 2) Cost Allocation: the structure for allocation of costs of uses and users.
- 3) Incentive Provision: the extent to which the utility will try to influence the behaviors of users through the rate structure.
- 4) Revenue Stability: the predictability and stability of the revenue flow.
- 5) Administrative Costs: the tradeoff between low administrative costs and a more complex rate structure.
- 6) Transparency: the pricing model must be understandable and provide a clear price signal.
- 7) Reliability: the system provides enough capacity for peak usage and expansion.
- 8) Affordability: the pricing model must be fair and equitable to all users and consider the extent of cross subsidies.

Rate studies are more than just a planning or finance document that aids in the decision making process. Among considerations are whether rates are distributed fairly among residential and commercial customers. It is important that accurate data is provided by the entity being evaluated and care must be taken to ensure that all expenses to the utility are truly related to the utility function as charged. Dialogue among organization leaders and the rate study team are an important issue in the planning process. A completed rate study serves as a planning methodology for future capital improvements and utility expansion.

A key tool in utility rate structuring is benchmarking with other agencies using similar utilities and a comparable customer base. However, it must be noted that all utilities are different in some respect and the model must ensure that each community's utilities are self-sufficient and meets the needs of the community. Additionally, many rate structures are structured differently based on the community's strategic plan or basic needs. Base rates and volume rates are structured differently in many communities and meter size varies from system to system. Additionally, the age of the system plays a key role in pricing.

A utility rate study is a road map for a designated period of time that helps planners make decisions for capital expansion, addition of new utilities, service to the community, and other key elements of the long term strategic plan. Rate studies are accomplished when necessary, but at a minimum when a rate increase is anticipated. Additionally, a successful rate model can serve as a tool for what-if analysis by planners. In this instance, a capital improvement projection can be measured to determine impact on rates thus aiding the decision making process. Several questions must be answered prior to beginning a rate analysis. These include:

- 1) What will happen to the customer base over the term of the rate study? Will it increase or decrease? Is there anything projected that will change the customer base?
- 2) Will costs escalate over the rate study term? Are increases or decreases in labor, materials, services, or benefits anticipated?
- 3) Will staffing levels or organizational structure change over the rate period? What is the anticipated level of growth for the organization?
- 4) What staff outside of the utility department support water and sewer through a percentage of their jobs? What percentage and can it be justified?
- 5) What contribution will need to be made to utility reserves? What is necessary for emergencies?
- 6) What capital improvements are planned over the rate period?
- 7) What capital replacements are projected?
- 8) What debt service is associated with water and sewer? Are any bonds planned for the future or included in capital expansion or improvement?

It is important to remember that the main goal of a rate study is to ensure the utility is completely self-sufficient. Bond sales can be supported by utility rates, but it is important to note that each utility, water or wastewater, should be able to stand on its own. To dip into general funds to pay utility expenses would add an unfair element as non-users would be forced to pay for a service not rendered. The water and wastewater fund should balance at the end of each year.

3. Economic Models for Water and Wastewater Demand

Due to the fact that there are so many variables influencing water demand and forecasting models, there are literally hundreds of statistical models in the literature that address community issues. Additionally, utility models

are divided into industrial, commercial, and residential segments to ensure fairness when determining price.

According to Bauman, Boland, & Hanemann, 1998, the *water requirements* approach is utilized when forecasting industrial use. While industrial usage is subject to varying variables, the most common assumes proportionality and utilizes the following basic assumptions.

$$x_i = \alpha_i y_i$$

$$x_i = \beta_i E_i$$

Where: x = water intake in an establishment in the *i*th type of industry

y= production by the establishment

E= number of employees in the establishment

α = water intake per unit of output in the *i*th type of industry

β = water intake per employee in the *i*th type of industry

Source: Bauman, D. D., Boland, J.J., & Hanemann, W.M., (1998) Urban water demand management and planning. New York: McGraw-Hill, Inc., page 34.

As noted, the basic assumptions in the formula leads directly to empirical modeling for demand while considering variables that affect each entity. These economic demand models address productivity in the manufacturing sector. They address demand based on the differences in each firm, the issue of demand elasticity in price setting, the derivatives of the demand function, and they provide formulas that address numeral calculations necessary to support variables present in organizations (Baumann, Boland, & Hanemann p.48, 1998).

Commercial property is the most complex and the hardest to regulate. There are numerous methodologies for commercial property. One example is a fixed amount based on anticipated use such as number of bathrooms. There are numerous methodologies for commercial usage. In the area of demand modeling, commercial property does not warrant the same consideration as residential and is usually treated much like industrial services.

Residential property is broken into categories by classification of either single or multiple family units. Residential includes single family, mobile home, low and high-density apartments and condos, and others. Historical data indicate that consumption varies based on classification. Economic and geographic considerations play a key role in economic models designed for residential demand forecasting.

Residential planning utilizes the *water use* approach similar to industrial demand. However, residential planning also utilizes economic modeling to ensure that conservation and poverty are addressed in pricing models. While water demand utilizes fixed coefficients to determine forecasts, the economic model treats demand forecasting as a behavioral model to address needs of the community. Analytical models for residential properties utilize historical data for consumer demand and customer usage (Baumann, Boland, & Hanemann p.56, 1998). A key element for data collection is metering for water consumption in mainly single-family homes. Multi-family units are usually metered as a building or complex.

According to Bauman, Boland, & Hanemann, 1998, the starting point for the economic theory is behavior optimization based on the utility function of the consumer. The assumption is that consumers have a limited budget for water and wastewater consumption. With μ being a function of what the customer consumes, the basic demand formula would be:

$$\mu = f(x_1, \dots, x_N)$$

Where:

μ = what the consumer consumes

X = amount of the *i*th commodity consumed

N = commodities

Source: Bauman, D. D., Boland, J.J., & Hanemann, W.M., (1998) Urban water demand management and planning. New York: McGraw-Hill, Inc., page 57.

As noted throughout this research, there are numerous economic models that support price and forecast modeling. This is an area that must be examined in future research.

4. Methodology

There are two accepted methodologies for performing rate requirements to keep a utility system financially viable. The “cash needs” methodology is used for municipal utilities and the “utility” methodology for investor-owned utilities. The two methodologies are very different with the utility methodology using indicators such as operating and maintenance, taxes, depreciation, and fair rate return on investment. This research concentrates on the “cash needs” methodology as utilized in a government entity responsible to citizens and not intending to operate for a profit.

As noted earlier, this research focuses on water and wastewater pricing models. However, it is important to note that utilities are diversified and many include other services such as solid waste or irrigation. Rate studies rely on historical data provided by the governmental institution. Historical data includes prior rate studies, capital expenses, customer information, operations expenses, current rate schedules, and consumption. The premise is that each utility will pay expenses for administrative, operational, maintenance, capital improvement, debt service, and maintain adequate reserves to operate the system in an emergency. Each system must be self sufficient. In other words, water revenues must pay for water expenses. The same is true for wastewater, irrigation, solid waste, etc.

To determine rate requirements, the expense portion of a typical rate model is divided into four categories; operating expenses, debt service, equipment renewal and replacement, and capital funding. It is important to note that each municipality is different. It is impossible to include each contingency in this paper. Therefore, it is critical that each rate model be thoroughly researched.

A typical completed rate model is a two-part rate structure consisting of a unit rate, usually referred to as a “commodity” charge, and a fixed rate known as a “capacity” charge. The unit rate, or commodity fee, is the monthly charge for consumption while the capacity charge covers the fixed cost for the utility to provide service. Depending on the administrative rules of the utility, a customer may pay a capacity charge even if they have zero consumption for a given month unless their system is completely shut down.

Commodity charges are for costs that are variable such as treatment costs, equipment rental, testing, replacements, etc. Capacity costs are for fixed expenses such as personnel, supplies, mailing, telephone charges, etc. While there are a lot more to the model than the few items mentioned, it is important to break down expenses into two categories for proper billing.

Operating expenses include anything that is required for operations. This includes maintenance, administration and customer service. Reserves requirements include a percentage of debt and operating expense set aside for emergencies. Existing debt includes principle and interest on existing loans or bonds. This includes principal and interest on water or wastewater utility-related instruments.

Capital funding includes rates set aside for capital improvements in a given year. This expense is designed for pay as you go projects paid from current revenues or accruals. Other expense elements include interdepartmental expenses, in-lieu taxes, and interest earnings (considered a credit to expenses).

Operating Expenses	Debt service (current & projected)	Equipment renewal & replacement	Capital improvement
Administration	Bonds		Plant Expansion
Water production	Loans	Water production	Building
Wastewater treatment		Wastewater treatment	Wells
Construction Maintenance		Construction Maintenance	Tanks
Irrigation Service		Customer service	Pump stations
Customer service			School lines
Governmental services		Engineer & construction management	
Engineer & construction management			

To determine annual revenue requirements, the following areas must be examined; other fees and services, total from rate requirements, and revenues from existing rates. Once added together and other factors considered, the need for a rate increase can be determined. Interest earnings, fines, forfeitures, and miscellaneous fees may be considered, but the majority of required revenue must come from rate charges. The chart below demonstrates expense elements for a typical rate model.

Table 2. Revenue Sources (Typical Rate Model)				
Customers	Meter installation	Interest income	Licenses & Permits	Misc. Revenues

Other issues that must be considered include the calculation of Equivalent Residential Units (ERU). Due to the fact that residential homes do not place equal demand on utilities, ERU's are determined to calculate charges for single-family homes, multi-family, condos, and other places of residences. Single-family homes usually have more property and this usually results in the highest consumption. Duplexes, multi-family, etc. are then charged a percentage based on calculations from historical data. Commercial property will be charged ERU's based on historical consumption and size of meter.

5. Pricing Structures

The purpose of a utility rate study is to allocate costs according to the classification of customers. It is imperative that entities are treated fairly. Commercial property, single-family homes, apartments, condos, all use services differently. It is important to ensure that rates are fairly distributed among user classes. A successful rate study provides the municipality with the ability to base charges for services on the true cost to each user classification.

Rajah and Smith (1993) studied pricing models in Great Britain and suggested that municipalities select from five fiscal models to determine pricing. England utilizes similar variables as those utilized in the United States. Capacity and commodity charges are levied and charges are based on usage in most cases. Rajah and Smith emphasize that efficiency in pricing and administration is an important element when managing water utilities. Their five models include: 1) a license fee where all users pay exactly the same amount, 2) metered charges based on consumption, 3) banded charges based on the number of people in the household, 4) banded charges based on the type of property, and 5) banded charges based on property value. Research indicates that most successful rate models take variables from all five.

Discrete pricing in the form of block rate schedules are a popular methodology for utility rates. According to Taylor (1975), price is associated with the block where consumption as a marginal price and an average price. Block rate pricing allows municipalities to adjust utility rates for issues such as conservation or poverty.

In 1976, Nordin defined a linear demand function for water which included consideration of consumer income. This model:

$$Q = \beta_0 + \beta_1 P + \beta_2 MP + \beta_3 D + \beta_4 Y$$

Where:

- Q = units of water purchased
- P = a price vector for other relevant goods
- MP = marginal price of water in the block consumption
- D = Lump-sum income effect
- Y = consumer income

In this case the difference between the marginal price and the price typically charges becomes a tariff for the community. However, this method is necessary to reduce costs on those who cannot afford to pay. At the same time an inclining block rate for conservation places a burden on those who utilize the most water in an effort to encourage reduce usage. Research indicates that most block models are dependent upon available data and can be biased or inconsistent (Deller, Chicoine, & Ramamurthy, 1986). Their research suggests, although not conclusively, that instrumentation introduced by Judge, et.al, in 1986. This methodology provides a proxy for troublesome variables and reduces inconsistency in the data. Two specific instruments are suggested to remove data error bias in the 1986 study. Regardless of the demand model selected, care must be taken to remove bias due to inaccurate data.

6. Forecasting

As with utility pricing models, there are numerous forecasting models to determine future demand for water consumption and wastewater processing. Water consumption is usually measured through meters. This provides a historical perspective for past consumption. Wastewater is usually measured by consumption of water. Metered water is a critical element used in the determination of operations, capacity and costs.

Economic and growth predictions must also be forecasted to determine future consumption. Environmental

factors play a key role and are usually the most abused variables in a forecasting model. In 1991, the City of Cape Coral hired an engineering firm to conduct a utility rate update for the City water and wastewater utility system. The forecasting of future revenues used as a basis for the study was critically flawed leading to several problems and the loss of consumer confidence.

According to Anderson and Forrer (2001), four issues contributed to the forecasting model used in the study producing inaccurate projections: (1) the City was installing 14 square miles of sewer system that was completed behind schedule; (2) the City was installing an irrigation system to homes. These accounts were added at a slower than anticipated pace; (3) the growth rate for the City was anticipated to continue at the 8% level experienced in the 1980s. In fact the rate dropped to approximately 3%; and (4) the data provided by the City for water and sewer accounts were inaccurate.

Based on account data provided by the City in the 1991 rate study, water accounts were predicted to reach 28,979 and wastewater accounts 23,088 in 1992. The City reported that actual water accounts for 1992 reached 37,098 while wastewater accounts rose to 23,705. The study predicted that the City would make \$15,470,594 during that first year. Actual revenues were only \$15,406,209. The difference of \$96,708 for that first year was insignificant. However, the larger question is how revenues could be short at all when actual accounts appeared to exceed predicted accounts by such a significant margin.

The problem worsened in the second year as the real impact of a faulty forecast was realized. Projections for that year called for 35,327 water accounts and 25,009 wastewater accounts. City statistics for 1993 revealed that actual water accounts reached 38,315 while sewer accounts rose to 23,342. Projected revenues for 1993, based on the rate study were \$19,147,161. Actual utility revenues were \$15,406,209, representing a difference of \$3,740,952. Again, actual accounts appeared to exceed predicted accounts and, given the wide range of error in estimating revenues, there was substantial reason to doubt the ability of the forecasting study to accurately estimate utility revenues.

In 1994, City staff determined that the account data utilized in the 1991 study were flawed and corrected the account totals for future use. As evidence of how far the data were off, the 1991 study had predicted that the City would have 37,044 water accounts and 39,933 wastewater accounts in 1994. Using the 1994 adjusted data, the prediction was for 28,891 water accounts and 17,344 wastewater accounts. The actual figures for 1994 were 28,152 water accounts and 16,203 wastewater accounts. The inflated rate study projected \$24,228,719 in utility revenues for 1994. Actual revenues realized were \$14,523,876, almost \$10 million below the expected total.

The combination of erroneous data, slower than expected growth rate, slower than projected wastewater construction, and delays in securing irrigation connections created revenue flow problems for the City. Compounding the issue was the fact that City planners budgeted with the projected figures. In 1994, the City of Cape Coral budgeted almost \$1.6 million more than actual revenues. The 1991 rate study, in its executive summary indicated that, "from projections of revenues and expenses at existing rates, the water system appears to be self-sufficient only through Fiscal Year 1992 in terms of meeting its operating revenue needs from the standpoint of debt coverage." As later facts became known, this turned out to be a true statement. Clearly the efficiency and effectiveness of the rate study were handicapped by the data used and thus by the forecasting model developed (Anderson and Forrer, 2001).

Forecasts are estimates of future consumption. There are numerous acceptable forecasting models, but the goal is to be as accurate as possible. This is extremely difficult when measuring water and wastewater consumption due to the many variables that must be considered. However, it is critical that accuracy is achieved if a municipality is to provide adequate funding for the system.

Several issues to consider when designing a successful utility forecast are:

- Understanding management's operational issues
- Incorporate technology
- Make realistic promises
- Know how the forecast will be applied to decision- making
- Identify operative variables
- Use a band of projections and scenarios
- Monitor the project and keep management informed
- Work with management to develop operational models and variables important to organizational goals
- Explain validity and reliability issues to management
- Acquire management skills and perspectives

To this end, Bauman, Boland, & Hanemann, 1998 define several water consumption forecasting models. The first is a time series analysis where linear regression is used to establish a curve. The curve is then extended into the future and usage is projected based on historical data and projected growth. While this model can be accurate, it is difficult to consider all variables affecting consumption at every level.

For simple models without drastic change, a *bivariate model* may be utilized. The bivariate model is illustrated as:

$$Q = a + b * X$$

Where: Q = water use per unit of time
 X = explanatory variable
 a, b , = coefficients

A variation of the bivariate model is the *per capita requirements method*. This is a model utilized in many urban areas. The formula is illustrated as:

$$Q = b * P$$

Where: Q = average daily aggregate water use
 P = resident population in service area
 b = per capita water use

The *unit use coefficient method* is utilized when a variable can be explained by an economic or social factor. For example, area employment statistics could be used to explain usage in an office complex. A more complex forecasting the *multivariate model* is utilized. This model is utilized when multiple variables affect consumption. The formula is depicted as:

$$Q = a + b_1 * X_1 + b_2 * X_2 + \dots + b_n * X_n$$

Where: Q = water use per unit time
 X_i = explanatory variable i
 a, b = coefficients

There are other models that consider numerous variables that change with each municipality. There are also many pitfalls in forecasting that must be considered. Uncertainty in forecasting can occur when the model omits important variables. This is called *model misspecification*. Another common problem is *coefficient error*. This is due to errors such as inaccurate data or procedural errors. Additionally, *assumption error* occurs when forecasts about events are not accurate (Baumann, Boland, & Hanemann p.89, 1998). Other pitfalls in forecasting include:

- Failure to examine assumptions
- Limited expertise
- Lack of imagination
- Neglect of constraints
- Excessive optimism
- Reliance on mechanical extrapolation
- Premature closure
- Overspecification
- Computer system
- Processes
- Data accuracy or lack thereof
- Weak organizational structure
- Lack of management involvement

It is critical that forecasts are accurate and pitfalls are considered.

7. Conclusion

This research is a base document to support future research in the area of water and wastewater utility pricing. The paper attempts to identify elements of the demand function and pricing methodology that affects utility pricing. While it is virtually impossible to cover every model and variable in a short paper, this research identifies the basic elements of a utility rate study. Future research will explore individual pricing and demand models in an attempt to develop an optimal water and wastewater pricing model.

The main pricing variable is the block structure utilized by many municipalities when determining utility charges. Shinn (1985) indicated that consumers are not really sure whether they are looking at marginal costs or average prices. Municipalities use increasing or decreasing block pricing dependent upon the political and environmental issues they must address. Consumer perception of financial models may be based on biased information. It is extremely difficult for a consumer to read his/her meter and follow consumption on a monthly basis. Therefore, consumers may not completely understand the price of the utility.

It is imperative that municipalities build a rate model that addresses variables important to the community they serve. Due to the vast environmental differences, there are no “one size fits all” rate models. Rate models must be carefully crafted and communicated to consumers in term they understand.

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